CURRENT LIMIT ENGAGEMENT APPARATUS

FIELD OF THE INVENTION

[0001] This invention is related to the field of electrical connectors, and more specifically to the field of electrical connectors designed to reduce current inrush peaks during plug in.

BACKGROUND OF THE INVENTION

[0002] When an electronic device is plugged in or turned on in an AC or DC electrical circuit, the electric plug's male and female connections come together and high current immediately begins to flow through the pins. Once any contact (and sometimes before contact if an arc occurs) is made on the pins, full normal operating current flows through the device. Thus, in many electronic devices the pins are designed so that any part of the pins or socket can immediately handle the full normal operating current. If due to space (or other) constraints, the pins are not designed for an individual pin to handle the full normal operating current, there is a high probability of damage to the pins or the socket from arcing, overheating, or stress from the instant flow of full current. It is also possible that there will exist a safety hazard since many connectors designed to handle high currents have exposed metal parts allowing people to receive electric shocks or burns.

[0003] Other electronic devices include capacitors requiring initial charging once power is connected to the device. Once power is connected, the capacitors draw high current until they reach full charge. Capacitor lifespan and reliability can be improved by limiting the charging current to the capacitor. Some designs include resistors in series

with the capacitors to act as current limiters, however, it is only necessary to limit current to the capacitor during initial charge up, and once fully charged, the resistor is no longer necessary, and in fact, may cause continuous power dissipation during normal operation of the device. Other designs use a relay or transistor to limit the initial charge up current, however this solution still leaves a small series resistance, and requires extra components in the design of the device, thus slightly reducing the overall reliability of the device. Still other designs use a positive temperature coefficient (PTC) device that starts out with a high resistance while cold and decreases in resistance as it heats up. However, this solution still continually dissipates enough power to keep the PTC device hot, and adds an extra component to the design of the electronic device.

SUMMARY OF THE INVENTION

[0004] An electrical connector is constructed with at least one pin configured to provide different resistance values as the pin is engaged with a socket. When the connector is fully engaged with the socket the resistance of the connector is at a zero or minimal value. When the pin first contacts the socket, the pin includes a high series resistance minimizing the sudden inrush of current to an electrical device, and minimizing any arcing between the pin and the socket. As the pin engages the socket this series resistance decreases allowing the electronic device to utilize its full designed current with only minimal contact resistance between the pin and the socket.

[0005] Other aspects and advantages of the present invention will become apparent from the following detailed description, taken in conjunction with the accompanying drawings, illustrating by way of example the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] Figure 1 is a side view of an example embodiment of a current limit engagement apparatus according to the present invention.

[0007] Figure 2 is a cross-sectional view of a prior art connector configured to accept a current limit engagement apparatus according to the present invention.

[0008] Figure 3A is a cross-sectional view of an example embodiment of a current limit engagement apparatus as it is inserted into a prior art connector configured to accept the current limit engagement apparatus according to the present invention.

[0009] Figure 3B is a cross-sectional view of an example embodiment of a current limit engagement apparatus as it is inserted into a prior art connector configured to accept the current limit engagement apparatus according to the present invention.

[0010] Figure 3C is a cross-sectional view of an example embodiment of a current limit engagement apparatus as it is inserted into a prior art connector configured to accept the current limit engagement apparatus according to the present invention.

[0011] Figure 3D is a cross-sectional view of an example embodiment of a current limit engagement apparatus as it is inserted into a prior art connector configured to accept the current limit engagement apparatus according to the present invention.

[0012] Figure 3E is a cross-sectional view of an example embodiment of a current limit engagement apparatus as it is inserted into a prior art connector configured to accept the current limit engagement apparatus according to the present invention.

[0013] Figure 4 is a side view of an example embodiment of a current limit engagement apparatus according to the present invention.

[0014] Figure 5 is a side view of an example embodiment of a current limit engagement apparatus according to the present invention.

[0015] Figure 6 is a schematic representation of an example embodiment of a current limit engagement apparatus according to the present invention similar to that shown in Figure 1.

[0016] Figure 7 is a schematic representation of an example embodiment of a current limit engagement apparatus according to the present invention similar to that shown in Figures 4 and 5.

DETAILED DESCRIPTION

[0017] Figure 1 is a side view of an example embodiment of a current limit engagement apparatus according to the present invention. In this example embodiment of the present invention a two-pronged power plug is shown including a plug body **100,** a ground conductor **112,** a power conductor **114,** a cable **116** for connecting the plug to an electric device, a ground pin **102,** and a power pin including a current limiting apparatus. Note that in this example embodiment of the present invention, the ground pin **102** is longer than the power pin. This allows the ground pin to make first connection with a mating socket before the power pin starts to make a connection. In this example embodiment of the present invention the power pin includes a first segment **104,** with a high series resistive value to limit the initial inrush of current to the electric device, a second segment **106,** with a lower resistive value than the first segment **104,** a third segment **108,** with a lower resistive value than the second segment **106,** and a fourth segment **110,** with the lowest resistive value that is present during normal operation of the electric device. This example embodiment of the present invention is designed to mate with the socket from Figure 2. However, those of skill in the art will recognize that there are many possible configurations of pins and sockets available to the designer within the scope of the present invention. For

example, any number of pins may be used in the plug in any combination of normal low resistance pins and current limit engagement pins. Also the pin sizes and shapes may be varied as needed for a given design all within the scope of the present invention.

[0018] Those of skill in the art will recognize that this example embodiment of the present invention is but one of many possible embodiments within the scope of the present invention. While the terms "power pin" and "ground pin" are used in this particular embodiment of the present invention, other embodiments may use other terms to refer to the pin including the current limiting apparatus, and the normal pin without any current limiting apparatus.

[0019] Figure 2 is a cross-sectional view of a prior art connector configured to accept a current limit engagement apparatus according to the present invention. The socket shown in Figure 2 is simply a standard electric socket configured to accept the plug shown in Figure 1. This example socket includes a socket body **218**, a first contact **220** connected to a cable **228** by a first conductor **222**, and a second contact **224** connected to the cable **228** by a second conductor **226**.

[0020] Figure 3A is a cross-sectional view of an example embodiment of a current limit engagement apparatus as it is inserted into a prior art connector configured to accept the current limit engagement apparatus according to the present invention. In this example embodiment of the present invention the electrical plug of Figure 1 is shown as it is inserted into the socket of Figure 2. Figure 3A shows the plug from Figure 1 at the point during insertion where the ground pin **102** has just made contact with the second contact **224** completing the contact between the two grounds.

[0021] Figure 3B is a cross-sectional view of an example embodiment of a current limit engagement apparatus as it is inserted into a prior art connector configured to accept

the current limit engagement apparatus according to the present invention. Figure 3B is identical to Figure 3A, however the plug has been inserted further into the socket. In this figure the first segment **104** has now made contact with the first contact **220** in the socket. At this point the ground pin **102** is fully contacted with low resistance and the power pin is electrically connected to the first conductor **222** and whatever lies at the end of the socket cable **228** however there is a high series resistance between the first segment **104** and the power conductor **114**. This high series resistance limits the inrush of current to whatever electric device is at the end of the plug cable **116**.

[0022] Figure 3C is a cross-sectional view of an example embodiment of a current limit engagement apparatus as it is inserted into a prior art connector configured to accept the current limit engagement apparatus according to the present invention. Figure 3C is identical to Figure 3B, however the plug has been inserted further into the socket. In this figure the second segment **106** has now made contact with the first contact **220** in the socket. At this point the ground pin **102** is fully contacted with low resistance and the power pin is electrically connected to the first conductor **222** and whatever lies at the end of the socket cable **228** however there is still a significant series resistance between the second segment **106** and the power conductor **114**. This series resistance still acts to limit the inrush of current, but now includes a lower series resistance allowing more current flow into the electric device.

[0023] Figure 3D is a cross-sectional view of an example embodiment of a current limit engagement apparatus as it is inserted into a prior art connector configured to accept the current limit engagement apparatus according to the present invention. Figure 3D is identical to Figure 3C, however the plug has been inserted further into the socket. In this figure the third segment **108** has now made contact with the first contact **220** in the socket. At this point the ground pin **102** is fully contacted with low resistance and

the power pin is electrically connected to the first conductor **222** and whatever lies at the end of the socket cable **228** however there is still a small series resistance between the third segment **108** and the power conductor **114**.

[0024] Figure 3E is a cross-sectional view of an example embodiment of a current limit engagement apparatus as it is inserted into a prior art connector configured to accept the current limit engagement apparatus according to the present invention. Figure 3E is identical to Figure 3D, however the plug has been inserted fully into the socket. In this figure the fourth segment **110** has now made contact with the first contact **220** in the socket. At this point the ground pin **102** is fully contacted with low resistance and the power pin is electrically connected to the first conductor **222** and whatever lies at the end of the socket cable **228** with only a small contact resistance between the fourth segment **110** and the power conductor **114**. At this point the plug and socket are fully engaged and act as a normal low-resistance connection between the devices at the ends of the two cables **116** and **228**.

[0025] Figure 4 is a side view of an example embodiment of a current limit engagement apparatus according to the present invention. In this example embodiment of the present invention an electrical plug is designed including a plug body **400**, a ground pin **402**, a power pin **404**, a ground conductor **410**, a power conductor **412**, and a cable **414** connecting the plug to an electrical device. In this example embodiment the outer portion of the power pin **404** is non-conductive and wrapped by a resistive wire **406** similar to those used in sliding potentiometers. The inner portion **408** of the power pin is equivalent to the fourth segment **110** of the plug from Figure 1 and provides a low resistance normal connection to a socket. This example embodiment of the present invention is designed to mate with the socket from Figure 2. However, those of skill in the art will recognize that there are many possible configurations of

pins and sockets available to the designer within the scope of the present invention. For example, any number of pins may be used in the plug in any combination of normal low resistance pins and current limit engagement pins. Also the pin sizes and shapes may be varied as needed for a given design all within the scope of the present invention.

[0026] Figure 5 is a side view of an example embodiment of a current limit engagement apparatus according to the present invention. In this example embodiment of the present invention a plug is designed including a plug body **500**, a ground pin **502**, a power pin **504**, a ground conductor **508**, a power conductor **510**, and a cable **512** connecting the plug to an electrical device. In this example embodiment the outer portion of the power pin **504** is made of a resistive material. On initial contact with a socket, the current flowing through the power pin **504** must travel the entire length of the resistive material resulting in a large series resistance. As the pin is engaged further into the socket, the current needs to travel through less and less of the resistive material until the final inner portion **506** of the power pin **504** is reached. The inner portion **506** of the power pin is equivalent to the fourth segment **110** of the plug from Figure 1 and provides a low resistance normal connection to a socket. This example embodiment of the present invention is designed to mate with the socket from Figure 2. However, those of skill in the art will recognize that there are many possible configurations of pins and sockets available to the designer within the scope of the present invention. For example, any number of pins may be used in the plug in any combination of normal low resistance pins and current limit engagement pins. Also the pin sizes and shapes may be varied as needed for a given design all within the scope of the present invention.

[0027] Figure 6 is a schematic representation of an example embodiment of a current limit engagement apparatus according to the present invention similar to that shown in Figure 1. In this example embodiment of the present invention a power pin including four segments is shown being inserted into a socket including a ground contact **618** and a power contact **616**. At the point shown in this schematic the plug is inserted into the socket such that the first segment **614** of the power pin is in contact with the power contact **616**. The power pin also includes a second segment **610**, a third segment **606**, and a fourth segment **602**. The first segment **614** includes a first resistor **612**. The second segment **610** includes a second resistor **608**. The third segment **606** includes a third resistor **604** and the fourth segment **602** does not have a resistor. The three resistors are connected in series such that when the first segment **614** of the power pin is in contact with the power contact **616**, the current must flow through all three resistors. When the second segment **610** of the power pin is in contact with the power contact **616**, the current flows through the second and third resistors. When the third segment **606** of the power pin is in contact with the power contact **616**, the current flows through the third resistor. Finally, when the fourth segment **602** of the power pin is in contact with the power contact **616**, the current does not flow through any of the resistors. Throughout the insertion of the plug into the socket the ground pin **620** is in contact with the ground contact **618** and the plug cable **600** is connected to an electric device.

[0028] Figure 7 is a schematic representation of an example embodiment of a current limit engagement apparatus according to the present invention similar to that shown in Figures 4 and 5. In this example embodiment of the present invention a plug including a power pin and a ground pin **708** is configured to connect to an electric device through a cable **700**. The power pin includes a variable resistor **702** such that

as the plug is inserted into a socket the series resistance in the power pin is reduced from an initial large value to a very low value when the plug is fully engaged with the socket. The ground pin **708** is in contact with the ground contact **706** throughout the entire engagement of the plug with the socket. The power pin is contacted by the power contact **704** within the socket.

[0029] The foregoing description of the present invention has been presented for purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise form disclosed, and other modifications and variations may be possible in light of the above teachings. The embodiments were chosen and described in order to best explain the principles of the invention and its practical application to thereby enable others skilled in the art to best utilize the invention in various embodiments and various modifications as are suited to the particular use contemplated. It is intended that the appended claims be construed to include other alternative embodiments of the invention except insofar as limited by the prior art.